Incorporating Contextual Information in Recommender Systems Using a Multidimensional Approach

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“Incorporating Contextual Information in Recommender Systems Using a Multidimensional Approach”

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Outline

1. Motivation
2. Multidimensional Model (MM) for recommender systems (RS)
3. Rating estimation in RS base on MM using Reduction Based (RB) approach
4. Combined RB and classical CF approach
5. Evaluation of the combined approach (experiments and discussions)

Motivation

- To improve the quality of recommender systems
Motivation

- Example:
  What is the rating of “Apocalypse Now” for John?

  \[ \text{Rating}(\text{John, Apocalypse\_Now}) = R(J, A\_N) \]

  - John with a girlfriend \( R(J, A\_N) = 1 \) (min)
  - John with friends and beer \( R(J, A\_N) = 5 \) (max)

- What is the Rating\((J,A\_N)\)?
  It depends ... on the context of the rating

Motivation

- Idea: To add context in the recommender systems in order to improve quality of recommendations
Multidimensional Model

- n-D or Multidimensional model

2-D: Users, Items
  \[ R: \text{Users} \times \text{Items} \rightarrow \{r_1, \ldots, r_n\} \]

n-D: Users, Items, Context
  \[ R: \text{Users} \times \text{Items} \times \text{Context} \rightarrow \{r_1, \ldots, r_n\} \]
Multidimensional Model

- Example: context

\[\text{Context} = (\text{with\_whom}, \text{where}, \text{when}, \ldots)\]

\[R(\text{John}, \text{Apocalipsis\_Now}, \text{with\_GF}, \text{at\_night}, \text{at\_home}, \ldots) = 1\]

- n-D model formally:

  - \(D_1, \ldots, D_n\) – sequence of dimensions
  - each \(D_i = (\text{Attr}_{i1}, \ldots, \text{Attr}_{ik_i})\)
    some \(D_j\) can have attached hierarchies
  - \(S = D_1 \times \ldots \times D_n\) – recommendation space
  - \(R: S \rightarrow \{r_1, \ldots, r_n\}\) – rating function (rating cube)
Multidimensional Model

- Example: n-D model

- $D_i = \text{Users(Used}_\text{id}, \text{UName, UAddress)}$
- $D_k = \text{Time(Time}_\text{id}, \text{day, month, year)}$

$hierarchy(D_k) = (\text{Days/Seasons, Days/{weekday, weekend}})$
Multidimensional Model

- Example: Usage of hierarchies

Multidimensional Model

- Recommendation Problem:
  for $S = D_1 \times \ldots \times D_n$ and total $R$

  1. to select
     $TW = D_{i1}, \ldots, D_{ik}$ - “to whom” dimensions
     $W = D_{j1}, \ldots, D_{jm}$ - “what” dimensions

     $\{D_{i1}, \ldots, D_{ik}\} \cap \{D_{j1}, \ldots, D_{jm}\} = \emptyset$
Multidimensional Model

- Recommendation Problem:
  for $S = D_1 \times \ldots \times D_n$ and total $R$

2. to recommend
  for each $t$ from $D_{i_1} \times \ldots \times D_{i_k}$ ("to whom")
  a $t'$ from $D_{j_1} \times \ldots \times D_{j_m}$ ("what"), s.t.

$$t' = \arg \max \{R(t'')| \pi_{j_1}, \ldots, j_m(t'') \in W\} \quad \pi_{i_1}, \ldots, i_k(t'') = t$$

Example: recommendation problem

- $S =$ Movie $\times$ User $\times$ Place $\times$ Time $\times$ Company

  $TW = $ User, Company
  $W = $ Movie, Place, Time

  for $(J, G_F)$ to find $(m', p', t')$
  $(m', p', t') = \arg \max \{R(m, J, p, t, G_F)| (m, p, t) \in \text{Movie} \times \text{Place} \times \text{Time}\}$
Multidimensional Model

- n-D model allows one to recommend not only top-k items for a user or top-k users for an item but also ...

  top-k vectors with values that
  1. correspond to different dimensions
     (Shining, AtHome, Weekend)
  2. located on different levels of hierarchies of the dimensions
     (Thriller, AtHome, Winter)

- If R is not a total function, then we need to estimate missing values for R
Reduction Based Approach for Rating Estimation

Basic Idea: to adopt CF to a multidimensional setting, i.e.
- estimate the rating $R(u,i,c)$ for an item $i$ of a user $u$ in a context $c$
  using ratings that are
  1. made in the context similar to $c$
  2. made by users similar to $u$

Reduction Based Approach

- How to find ratings made in a context similar to a given one?

- ratings marked with grey are made in the “Theater” context

Reduction Based Approach

- How to find ratings made in a context similar to a given one?

- ratings marked with grey are made in the “Weekend” context
Reduction Based Approach

- How to find ratings made in a context similar to a given one?

- Intersection of ratings marked with grey on the left and right pictures corresponds to ratings made in the “Weekend in a Theatre” context

Reduction Based Approach

- How to find similar users having a fragment $S$ of the rating cube that contains ratings made in the similar context?

- Project $S$ to Users x Item, i.e. reduce n-D case to a classical 2-D one, and apply standard 2-D techniques to find similar users
Reduction Based Approach

- Example: reduction n-D to 2-D

Questions:

1. How to find contextual fragments of the rating cube?
2. Which of the fragments to use?
3. Does the approach really allows better rating estimations?
Motivation

- Estimation of $R(J, A_N)$ using CF:

- $R(J, A_N) = \text{AGGR} \left( R(u_1, A_N), \ldots, R(u_n, A_N) \right)$
  - $u_1, \ldots, u_n$ – users that are similar to John
  - If AGGR = AVG, $R(u_i, A_N)=5$, then $R(J, A_N)=5$
  - But, John is going to watch the movie with a girl friend
    $\Rightarrow$ John will be unhappy with the recommendation